Metabolism

Lecture 1

Introduction, Energy Balance, Respiratory Quotient (RQ) and Metabolic Rate (MR)

By the end of this lecture the student will be able to:

- ❖ Define the following terms (metabolism, anabolism catabolism, energy balance, respiratory quotient & metabolic rate
- ❖ Analyze energy balance
- ❖ List causes of positive and negative energy balance
- ❖ Enumerate constituents and functions of food
- ❖ Clarify physiological and physical heat values
- ❖ List the factors affecting metabolic rate (M.R)

Metabolism

- This term refers to all chemical reactions & energy transformations that occur in the body.
- The metabolic reactions are divided into two types, both reactions occur in all tissues,:-

1- Anabolic reactions: Synthesis of big molecules that support growth of new cells and tissue structure & energy storage for use in the future. It consumes energy.

2- Catabolic reactions: Breakdown of big materials via oxidation of food stuffs into small ones with liberation of energy that is used for many ……

Internal work:

A- Chemical work i.e. synthesis of new molecules & cells.

B- Electric work e.g. for production & maintenance of RMP & AP.

C- Other work e.g. active transport across the cell membrane.

D- Heat regulation.

External work: Muscle contraction.

Energy Input

Your energy input is coming from the food that you eat, Calories are coming from our food. **SO,**

Calories (energy) provided by 3 macronutrients:

1. Fat
2. Carbohydrate
3. Protein

* A typical mixed meal consists of carbohydrates, proteins and lipids.

* An optimal diet includes, in addition to sufficient water, CHO, protein, fat, minerals and vitamins.

A balanced diet is important for health, and certain substances obtained from the diet are essential to life.

A- Carbohydrates (≈ for production of energy).

B- Fats (≈ for production of energy).

C- Proteins (≈ for building of new cells).

D- Vitamins & minerals (≈ for regulation of metabolic reactions & maintenance of health).

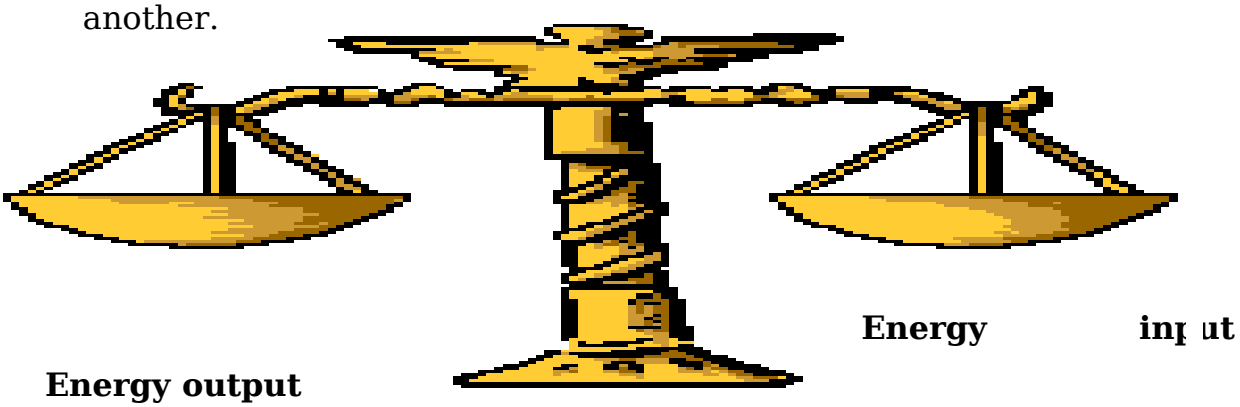
The energy liberated in the body:-

1- (≈ 75 - 80 %) appears as thermal energy (heat).

2- (≈ 20-25 %) stored in the form of organic phosphate compounds (e.g. ATP & CP). The stored type of energy is converted into work that can be done by the cells.

Energy Balance

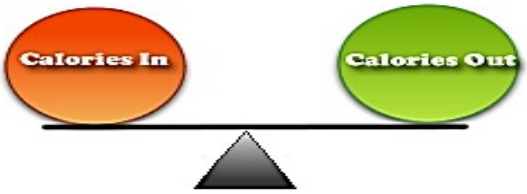
Energy is neither created nor destroyed, it is converted from one form to another.



Energy input

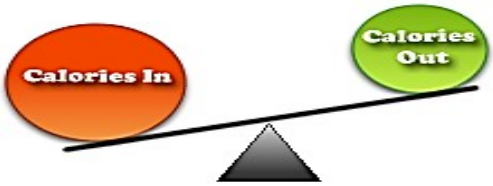
Energy output

=



Weight Maintained
Isocaloric Balance
Energy In = Energy Out

Weight Loss
Negative Caloric Balance
Energy In < Energy Out



Weight Gain
Positive Caloric Balance
Energy In > Energy Out

The caloric value of the dietary intake must be approximately equal to the energy expended if body weight is to be maintained and also for homeostasis.

Variation in energy balance

1- (+ ve) energy balance: If energy intake (input) is more than energy output → more anabolism and more energy stores → increase in body weight as in obesity & growth of children.

2- (- ve) energy balance: If energy intake is less than energy output → the endogenous energy stores are catabolized more than normal → loss of body weight e.g. under nutrition, starvation and anorexia nervosa.

Daily caloric requirements

- The average adult must take in about 2000 kcal/d.
- Caloric requirements above the basal level depend on the individual's activity.

- The average sedentary student (or professor) needs another 500 kcal, whereas a lumberjack needs up to 3000 additional kcal per day.
- So, In addition to the 2000 kcal/d necessary to meet basal needs, 500 to 2500 kcal/d (or more) are required to meet the energy demands of daily activities.

Unit of Energy

- The standard unit of heat energy is the calorie (cal).
- Calorie (cal): It is the amount of heat energy necessary to raise the temperature of 1 g of water 1 degree, from 15 °C to 16 °C.
- Calorie (cal) = gram calorie = small calorie = standard calorie.
- The unit commonly used in physiology and medicine is the Calorie (kilocalorie; kcal).
- Kilocalorie = 1000 calorie.
- Kilocalorie (Kcal = capital C): the amount of heat energy required to raise the temperature of one Kg. of water from 15 -16 °C.

Physical heat value

Physical heat value: The amount of energy liberated when 1 gram of food substance is completely oxidized outside the body.

Caloric value of food (physical heat value)

- CHO ---------- 4.1 KCal/g
- Fats----------9.3 KCal/g
- Protein----------5.3 KCal/g

Estimation of energy intake

The amount of energy intake is obtained by multiplying the ingested amount of each type of food in grams X its physiological heat value.

Physiological heat value

The amount of energy liberated by 1 gram of food substance when it is completely oxidized inside the body.

- CHO----------4.0 KCal/g.
- Fats----------9.0 KCal/g.
- Protein----------4.1 KCal/g. ??????

N.B.:

*** The physiological heat value of protein (4.1) is less than its physical heat value (5.3) due to ???? incomplete oxidation of protein inside the body.

Respiratory Quotient (RQ)

The respiratory quotient (RQ) is the ratio in the steady state of the volume of CO_2 produced to the volume of O_2 consumed per unit of time.

$$RQ = \frac{\text{Volume of } CO_2 \text{ produced}}{\text{Volume of } O_2 \text{ consumption.}}$$ As a ratio at the same time.

N.B.: It should be distinguished from the respiratory exchange ratio (R), which is the ratio of CO_2 to O_2 at any given time. That R is affected by factors other than metabolism.

Importance of RQ:

1. Determines the nature of food substance oxidized and utilized in different tissues and under different conditions.
   i. RQ of CHO ---------- = 1. Why???
   ii. RQ of Fat ---------- = 0.7.
   iii. RQ of Protein---------- = 0.82.
2. Indicates the transformation of one food substance into another in the body.

CHO (rich in O_2) →Fat (poor in O_2) →more CO_2 production → higher RQ.

3. Help in calculating the metabolic rate by determination of the caloric (heat) value of O_2.
4. Negative RQ. During secretion of gastric juice, the stomach has a negative R because it takes up more CO_2 from the arterial blood than it puts into the venous blood.

Why RQ of CHO ---------- = 1 ???

Carbohydrate: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ (glucose)

RQ = 6/6 = 1.00

This is because H and O are present in carbohydrate in the same proportions as in water, whereas in the various fats, extra O_2 is necessary for the formation of H_2O.

RQ of the brain is regularly 0.97– 0.99, indicating that *its principal but not its only fuel is carbohydrate*.

Metabolic Rate

Def.:- The amount of energy liberated per unit of time.

It is better to expressed per square meter surface area Cal/h/m^2

* Most of body energy production appears as heat (thermal energy) ≈ 80%
* ≈ 20% as stored energy by forming energy-rich compounds (in the form of ATP & CP).

Stored energy is transformed into work: a- External work (for Ms. Contraction).

b- Internal work (heat regulation, electric & chemical…).

Estimation of Metabolic Rate by the following methods:-

1- Direct calorimetry. **2-** Indirect calorimetry. **3-** Simplified indirect calorimetry.

Factors affecting MR

1. Muscular exercise → Increase the metabolic rate (MR).

2. Pregnancy → Increase the MR, Why? A)……. B) ……..

3. Sleep → Decrease the MR.

4. Environmental temperature:

** Exposure to cold →↑ heat producing mechanisms e.g. shivering→ increase MR.

** Exposure to hot. → ↑ Body temp. → ↑ Metabolic processes→ increase MR about 14 % for each degree Celsius of elevation.

N.B.: The curve relating the metabolic rate to the environmental temperature is U-shaped.

5. Age: ** Max. MR during early life.

** Declines with advanced age.

6. Sex: MR increased in male than in females. **Why?** ……..

7. Recent ingestion of food→ ↑ "Increase" the MR. **Why?** Because of their SDA "???".

8. Body size (height, weight and surface area) → Increase body size→ ↑ MR.

9. Race: Different races→ different MR.

10. Emotions →↑ MR by: 1- Increase Ms. Tone. 2- Epinephrine secretion.

11. Endocrinal factors: e.g. 1- Catecholamine →↑ MR. 2- Thyroxin →↑ MR.

12. Body temperature: Increase body temp. → ↑ MR.

13. Starvation → ↓ decrease the MR by: 1- Decrease sympathetic activity.
2- Decrease thyroid hormones.

SUGGESTED TEXTBOOKS

1. Ganong's "Review of Medical Physiology", 25th edition, chapter 72, pages 459-467
2. Guyton and Hall "Textbook of Medical Physiology", 12th editio chapter 72, pages 862-865
3. Sembulingam "Essentials of Medical Physiology", 6th edition, chapter 124 page 710